

Sustainable Landscapes and Ecosystem Valuation in Woodlands, Savannas and Systems of Trees Outside of Forests in Malawi, Kenya and Senegal

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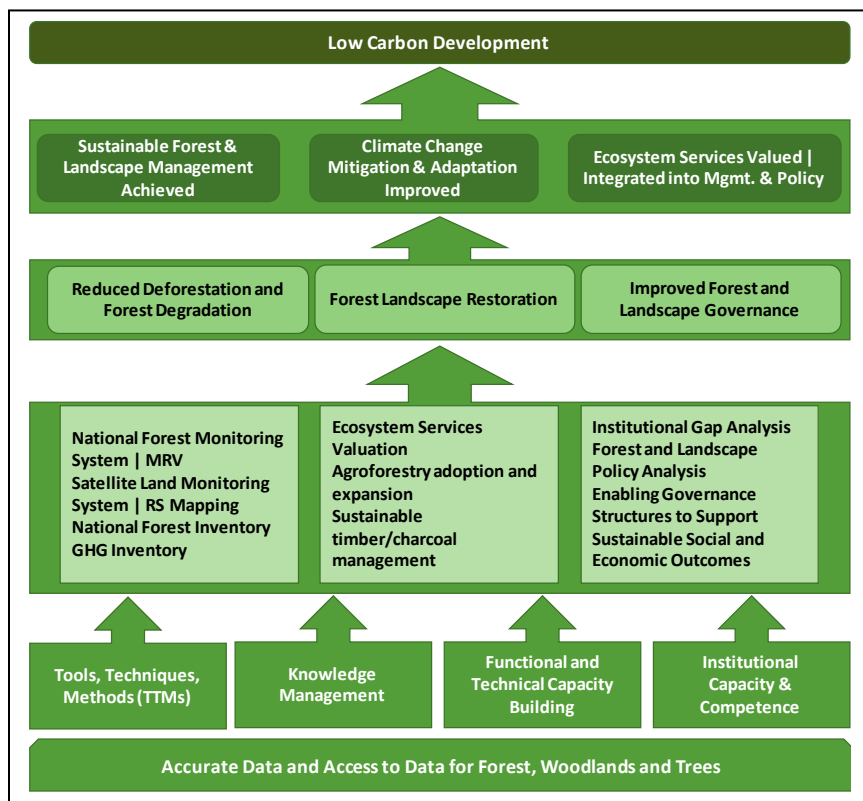
Introduction

I am currently working on several projects related to *Land Use and Land Cover Change and Ecosystems*. These projects are focused on i) Tools, Techniques and Methods (TTM), ii) Knowledge and Data Management (KDM) systems, and iii) Training and Capacity Building (TCB) models to address *Sustainable Landscapes, Carbon Management and Ecosystem Services Valuation*. These projects build upon prior work and experience with support from USAID, GEF/UNEP, World Bank Forest Investment Program (FIP Monitoring and Reporting Toolkit) and NASA (LCLUC). We have worked extensively in Malawi, Kenya and Senegal. We have worked with LUNAR and UCAD extensively, hosting faculty from these institutions and graduate students from these countries. In Kenya we have worked extensively with KEFRI and ICRAF. The focus of the TTMs is support for national and subnational (district and community) technical means for National Forest Monitoring Systems (NFMS), sustainable forest management (SFM) and ecosystem services valuation (ESV), applied at the landscape level. These TTMs are embedded in a capacity building model, also used in these previous projects.

Theory of Change

Although there has been significant work in recent years on mapping land cover change in closed forests of the humid equatorial tropics, it is important to examine woodland forests of the drier tropics. Woodland forests and Savannas are

under significant pressures from agricultural expansion, fuelwood culling, and climate-change-induced biomass collapse. These pressures diminish landscape productivity and ecosystem services and adversely affect livelihoods of millions of rural people living in extreme poverty. There is now a critical need to build capacities for landscape-scale monitoring of woodland forests, Savannas and trees outside of forests (TOF).



While *basic science* has made great progress in the field of land change science, there are gaps in the *applied knowledge base* and in the capacity of governments and communities to manage natural resource capital. Action is needed to support climate change mitigation and adaptation and a broader *applications* program of sustainable landscape management incorporating ecosystems services observations, measurements, and valuation – an *actionable science* approach that uses the best scientific

and technical tools, techniques, and methods (TTMs) to build capacity to address *specific* needs of host governments and society in the region.

Framework for the Project

Woodland Forest Ecosystems. We focus on forest land cover change, but specifically address the woodland forest systems, as opposed to the popular focus on wet dense tropical forests. Woodlands and Savannas are significant ecosystems in terms of area and vulnerability. While biomass (and carbon) stocks are low per unit area, they are globally important. Because human population densities are high in these landscapes the impact of land cover change has serious implications for economic development and livelihoods. For people who live there, these systems provide a

range if critical ecosystems services, including energy, fodder, non-timber products, materials and more. At the same time, the demand for cultivated land has increased deforestation and degradation in these systems. One of the more salient aspects of woodlands is the prevalence of forest *degradation* – while global focus has been much on *deforestation* monitoring, the widespread *degradation* of woodlands inside and outside the forest estate is an important focal point for our new tools, techniques and methods (TTM).

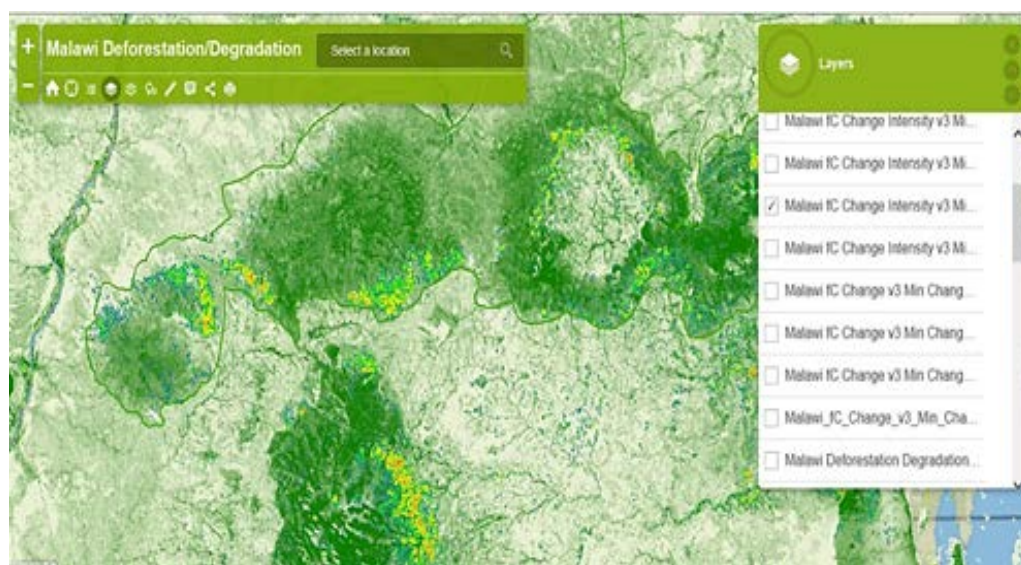
Systems of Trees Outside of Forests (TOF). The World Agroforestry Center often notes that the “future of trees is on farms”. This catchphrase reflects growing expert opinion that while forests world-wide are being degraded and converted, tree cover outside of forests is increasing at a rapid pace, especially in developing countries and in semi-arid landscapes. TOF includes agroforestry complexes, small holder plantations, orchards, energy farms and woodlots, hedgerows and shelterbelts, scattered individual trees and other woody perennial establishments in predominantly rural or peri-urban landscapes. The utilization of trees on farms provides natural products and economic value chains to land managers and a range of local co-benefits, including: water retention, increased site fertility and productivity, animal fodder, domestic energy from fuelwood and charcoal, biodiversity and more.

The Landscape Approach. Management of forests also requires management of land outside the forest zone. From our work in Malawi and Kenya we observe that rural communities respond to resource constraints (e.g. domestic charcoal) by degrading public forest reserves. At the same time evidence from our work in Malawi and from similar literature in West Africa suggests that small holders are often managing TOF systems to *promote* tree cover, to capture direct or indirect ecosystem service benefits. Evidence suggests that *small holders promote the establishment of TOF to capture the value of ecosystem services (ES), which include (a) perceived or realized co-benefits of trees, such as increasing water retention, and (b) direct value from tree products, such as food and fuel; both can be quantitatively assessed through formal econometric analysis.* This example demonstrates the need to use a landscape approach, which includes a range of “interacting” land covers (woodland forest and croplands) and sectors (forestry and agriculture). The landscape approach also provides a platform for including multiple ecosystem services in determining land management interventions (e.g. forest landscape restoration).

Ecosystem Services Valuation (ESV) and Low Carbon Development. An important aspect of the landscape approach above, is having TTMs for actual quantitative valuation of ecosystem services, and linking these values to preferences, choice, and benefits. This is most clear for catalyzing low carbon forest management. In our above example of rural communities promoting TOF, ESV can catalyze community-based Forest Landscape Restoration (FLR) and reduce land degradation and greenhouse gas emissions. ESV econometric analysis can be developed using formal quantitative methods of value capture by small holders, whether they sell products through a value chain or not – ie. whether they market the TOF products or use it domestically. Carbon in land cover, including carbon sequestration in activities such as REDD+ interventions and FLR, is an important ecosystem service, which can now be readily measured. Financial systems being developed (e.g. Green Climate Fund).

Advantages of Using Remote Sensing Data Combined with Field Data.

Our approach covers the landscape level of analysis using remote sensing data. These data can be used to map woodland and savanna degradation, as shown on the left for Malawi. The bright green, yellow and orange colors are detected hot spots of degradation. Then ground data can assess both biophysical attributes (e.g. biomass) and social attributes (e.g. economic valuation and livelihoods, promotion of TOF).



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EDUCATION

Indiana University, Biological Science, A.B., 1977
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University of New Hampshire, Natural Resources, Ph.D., 1992

APPOINTMENTS

Director, Global Observatory for Ecosystem Services, Michigan State University, 2005-present
Professor, Department of Forestry, Michigan State University, 2005-present
Professor, Department of Geography, Michigan State University, 1997-2005
Director, Center for Global Change and Earth Observations, 2002-2005
Director, Basic Science and Remote Sensing Initiative, Michigan State University, 1997-2003
Assistant Professor, Institute for the Study of Earth, Oceans, and Space, University of New Hampshire, 1992-1997

BIOGRAPHICAL SKETCH

David L. Skole is Professor of Forestry. His research focuses on the relationship between land use change, climate change and the use of geographical information for sustainable development and natural resource management. The current focus of his work is climate change mitigation and adaptation in international development, with a focus on carbon measurement and accounting for REDD+. He has more than 25 years experience with research on forestry and carbon. He was instrumental in constructing the first numerical carbon accounting model and has been spearheading the integration of satellite remote sensing into carbon accounting models. He has more than 100 peer-reviewed publications on land use change and forestry issues related to carbon emissions and sequestration. He has been a leading expert on global environmental monitoring, having been instrumental in developing several international programs related to land use, carbon and climate change. In recent years he has been a leading authority on measurement, reporting and verification for forest carbon projects and has developed and published several protocols for A/R and REDD projects.

He was formally recognized for his climate change research as an official member of the United Nation's Intergovernmental Panel on Climate Change that shared the 2007 Nobel Peace Prize. He is now active in the emerging carbon financial markets and applications of his research to carbon sequestration and climate change mitigation projects in developing countries. He has been active in developing methods for carbon offsets under cap and trade carbon regulations. He is currently supporting the California emissions mitigation programs through international forestry under the Governor's Climate and Forest Fund. He was a member of the Chicago Climate Exchange (CCX), and served as a member of its Offsets and Forestry Committee. He is the author of a very early book, *Beyond Oil: the Threat to Food and Fuel in the Coming Decades* that was published in 1986 and predicted the current oil and food crises. Dr. Skole is currently a Member of SilvaCarbon activity of OSTP and US Government Advisory Group on Carbon Accounting and a Member of the USDA/USFS Advisory Committee on Technical Guidelines for Quantifying Greenhouse Gas Sources and Sinks in the Forestry and Agriculture Sectors.

His work is now supporting international development programs of the US Government. He is group supports three major foreign assistance programs on REDD+ through USAID in India (Forest PLUS), Malawi (PERFORM) and Indonesia (LESTARI), and was senior investigator for the Carbon Benefits Program of UNEP and GEF. He is advising the Forest Investment Program (World Bank Group), and was instrumental in developing its monitoring and reporting toolkit. He was the charter Implementation Chairman of the United Nations Program on Global Observations of Land Cover, which is coordinating a monitoring program for land use change worldwide. Dr. Skole is past-Chair of the National Science Foundation Advisory Committee on Environmental Research and Education. He is also former Chairman of the International Geosphere Biosphere Programme's Core Project on Land Use and Cover Change. He has been a member of several committees of the National Academies including the

Committee on Geographical Foundations of Agenda 21, and co author of the report, *Down to Earth, the Geographic Information for Sustainable Development in Africa*, which was a key element of the U.S. position at the World Summit on Sustainable Development. He served on the Committee to Review the Climate Change Science Program Strategic Plan, the Committee on Geographic Sciences, and the Committee on Social and Behavioral Research Priorities for Environmental Decision making. Currently he serves as a member of the Standing Committee on Earth Science Applications from Space.

He has advised NASA, EPA, and US Agency for International Development as a consultant and investigator. He is the director of the Tropical Rain Forest Information Center, a NASA data and information center. He has been an advisor to both international public and the private sectors, including large environmental projects such as the Brazilian SIVAM project which is developing improved regional monitoring and management capabilities for the Amazon region under contract to several U.S. companies.

Most of Dr. Skole's work is centered in developing countries, primarily the tropical forest regions of the world. His research team works closely with governments and local communities in more than 50 scientists and government natural resources managers in a dozen countries, including Ghana, Senegal, Kenya, Malawi, Costa Rica, Brazil, Indonesia, Laos, Thailand, Philippines, Malaysia, Vietnam and others.

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Director, Basic Science and Remote Sensing Initiative, Michigan State University, 1997 - 2002
Research Professor, Institute for The Study of Earth Oceans And Space, University of New Hampshire.
1992-1997

EDUCATION

Ph.D., Natural Resources, University of New Hampshire
M.S., Environmental Science, Indiana University
A.B., Biological Science, Indiana University

MEMBERSHIP OF LEARNED SOCIETIES

American Association for the Advancement of Science
American Association of Geographers
American Society for Photogrammetry and Remote Sensing.

AWARDS AND RECOGNITION

Distinguished Service Recognition, National Science Foundation, 2016
Classics in Physical Geography, paper award, 2008
Nobel Peace Prize, 2007
Certificate of appreciation for leadership, National Science Foundation, 2005
Recognition of achievement at the centennial meeting, American Association of Geographers, 2004
Appointed to the Geographical Sciences Committee, The National Academies, 2004
Research achievement noted by the US Climate Change Science Program, 2004
Letter of commendation for outstanding work, The National Academies, 2002
Second most influential paper in the first decade of global change research, ISI
Research achievement recognized by John H. Gibbons, Director, OSTP, January 6 1995
Research achievement from President William Clinton, *Science in the National Interest*, 1994
Research results placed on exhibit at the National Air and Space Museum, 1994

PUBLICATIONS

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Jayne T.S., Sitko N.J., Mason N.M., Skole D. 2017. Input Subsidy Programs and Climate Smart Agriculture: Current Realities and Future Potential. In: Lipper L., McCarthy N., Zilberman D., Asfaw S., Branca G. (eds) *Climate Smart Agriculture*. Natural Resource Management and Policy, vol 52. Springer,

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TESTIMONY AND OFFICIAL BRIEFS

Executive Office of the President

Carbon Offsets, invited briefing for the President's Council of Advisors on Science and Technology, 122 December 2009.

Patterns to Processes: Scientific Challenges for Water Research, invited briefing for the Director and Associate Director for Science, Office of Science and Technology Policy, 19 October 2004, Washington, D.C.

Scientific Challenges for Water Research, invited briefing for the National Science and Technology Council, Office of Science and Technology Policy, 16 December 2004, White Conference Center, Washington, D.C.

Advances in Land Cover and Land Use Change Research, invited briefing for the Assistant Director for Environment, Office of Science and Technology Policy, July 1999, White House Conference Center, Washington, D.C.

Congress

The Natural Environment and Indigenous People of Brazil, prepared statement as testimony before the House Foreign Affairs Committee, Subcommittee on Western Hemisphere Affairs, May 10, 1994.

United States Foreign Assistance and Tropical Deforestation, In, *Tropical Deforestation, Hearings before the Subcommittee on International Organizations of the Committee on Foreign Affairs*, House of Representatives, United States Congress, September 18, 1981.

Governor's Office

Michigan's Land Use Resource Project, invited testimony before the Governor's Land Use Leadership Council, 24 March, 2003, Senate Hearing Room, Lansing MI.

BOOKS

Gutman, G., A. Janetos, C. Justice, E. Moran, J. Mustard, R. Rindfuss, D. Skole, B. Turner (eds.) 2004. *Land Change Science: Observing, Monitoring, and Understanding Trajectories of Change on the Earth's Surface*. Kluwer Academic Publishers, Dordrecht, 459 pp.

Gever, J., R. Kaufmann, D.L. Skole and C.J. Vorosmarty, 1991. *Beyond Oil: The Threat to Food and Fuel in Coming Decades*, University Press of Colorado, 304 pp.

LEAD AUTHORSHIP ON SIGNIFICANT PEER REVIEWED REPORTS

Thriving on Our Changing Planet: A Decadal Strategy for Earth Observations from Space, Earth Sciences Board, National Academies, January 2018.

America's Future: Environmental Research and Education for a Thriving Century, 10-year Outlook for the National Science Foundation, NSF, 2015

GLP Report Challenges and Prospects for REDD+ in Africa, START Washington DC, 2012

GEO-4: Fourth Global Environment Outlook, Chapter 3: Land (land degradation and forests), United Nations Environment Program, Nairobi, 2005.

Exploring Our Planet for the Benefit of Society, NASA Earth Science and Applications from Space Strategic Roadmap, National Aeronautics and Space Administration, Washington, DC., 2005

Complex Environmental Systems: pathways to the future, National Science Foundation, Washington, DC, 2005.

Implementing Climate and Global Change Research: a review of the final US climate change science program strategic plan. National Academies Press, Washington, DC, 2004

Planning Climate and Global Change Research: a review of the US climate change science program strategic plan. National Academies Press, Washington, DC, 2003

Complex Environmental Systems: synthesis for Earth, life and society in the 21st century, National Science Foundation, Washington DC., 2003

Down to Earth: Geographic Information for Sustainable Development in Africa, National Academies Press, Washington, DC., 2002

Land Use, Land Use Change, and Forestry, special report to the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 2000.

Land Use and Cover Change Implementation Strategy, International Geosphere Biosphere Program report 48, Stockholm Sweden, 1999.

Land Use and Land Cover Change Science/Research Plan, International Geosphere Biosphere Program, report 35, Stockholm, Sweden, 1995.

Relating land use and global land-cover change: A proposal for an IGBP-HDP core project. Report from the IGBP-HDP Working Group on Land-Use/Land-Cover Change. Joint publication of the International Geosphere-Biosphere Programme (Report No. 24) and the Human Dimensions of Global Environmental Change Programme (Report No. 5). Stockholm: Royal Swedish Academy of Sciences 1993.

EDITORIAL BOARDS

Remote Sensing in Earth System Science, Ecology and Carbon Cycle, subject matter editor, Springer
Regional Environmental Change, Springer, Berlin (present)

Land, Special Editor, Special edition on REDD+, MDPI (present)

Regional Environmental Change, Springer, Editorial Board member (completed)

COMMITTEES OF THE NATIONAL ACADEMIES

Committee on the Decadal Survey of Earth Science and Applications from Space, Space Studies Board, 2016-2018

Standing Committee on Earth Science and Applications from Space, Space Studies Board, 2012 - present

Standing Committee on Geographical Sciences, Board on Earth Sciences and Resources, 2004 – 2010

Committee to Review the U.S. Climate Change Science Program, Division on Earth and Life Studies
Division on Engineering and Physical Sciences, and Division of Behavioral and Social Sciences and Education, 2002 – 2004

Committee on Social and Behavioral Science Research Priorities for Environmental Decision Making, Division of Behavioral and Social Sciences and Education, 2003 - 2005

Committee on Ecological Impacts of Road Density, Division on Earth and Life Studies
Transportation Research Board, 2002 – 2003.

Committee on Geographical Foundations of Agenda 21, Division on Earth and Life Sciences, 2001-2002.

FEDERAL ADVISORY COMMITTEES

Member, SilvaCarbon, OSTP and US Government Advisory Group on Carbon Accounting

Member, USDA/USFS Forestry Working Group, Advisory Committee on Technical Guidelines for Quantifying Greenhouse Gas Sources and Sinks in the Forestry and Agriculture Sectors

Chair, Advisory Committee for Environmental Research and Education, National Science Foundation

Strategic Roadmap Planning Committee, National Aeronautics and Space Administration

Land Use and Land Cover Change Steering Committee, U.S. Climate Change Science Program (interagency)

Advisory Committee, The Midwestern Regional Center of the National Institute for Global Environmental Change. US Department of Energy

Landsat 7 Science Team, National Aeronautics and Space Administration

Science Steering Committee, Large Scale Amazon Basin Experiment (LBA), 1997-2000, National Aeronautics and Space Administration

New Data and Information Systems Planning Committee, Earth Science and Applications, National Aeronautics and Space Administration.

INTERNATIONAL COMMITTEES AND PANELS

Chair, Forest Cover Characteristics and Change Implementation Team, Global Observation of Forest Cover program, United Nations Global Terrestrial Observing System.

Chair, Fine Resolution Remote Sensing Design Team, Global Observations of Forest Cover Project, Committee on Earth Observation Satellites

Chair, Core Project on Land Use and Cover Change, International Geosphere Biosphere Program (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP), Barcelona, Spain.

Scientific Committee of the International Geosphere-Biosphere Programme, International Council of Scientific Unions, Stockholm, Sweden.

Steering Committee of the International Human Dimensions Programme on Global Environmental Change, International Council of Scientific Unions, Bonn, Germany.

Standing Committee for the International Geosphere-Biosphere Program's Data and Information System Office, Toulouse, France.

Science Advisory Panel for the Southeast Asian Regional Committee for START (governing body of the World Bank/GEF/UNDP sponsored activity of the IGBP, IHDP, and World Climate Research Program), Bangkok, Thailand.

Lead Author, *Intergovernmental Panel on Climate Change Special Report on Land Use, Land Use Change and Forestry*, Intergovernmental Panel on Climate Change, Framework Convention on Climate Change, United Nations.

CORPORATE ADVISORY BOARDS

Academic Advisory Council, Spot Image, Inc., Reston Virginia, USA.

Forestry Committee, Chicago Climate Exchange

Offset Committee, Chicago Climate Exchange

RECENT PRIVATE SECTOR CONSULTING

Forest Investment Program, the World Bank

Chemonics International, for REDD+ in Panama

ICF International for support to USDA carbon accounting guidelines

The Boeing Company, Seattle, WA, for their Resource 21 Program.

Raytheon Company, Electronic Systems Division, Lexington, MA. for their Wide Area Monitoring and Surveillance Programs

Hughes Applied Information Systems, for development of Environmental Information Systems.

National Information Infrastructure Testbed Consortium, for development of the Earth Data System prototype.

SELECTED GRANTS AND CONTRACTS

PI, LESTARI project in Indonesia, USAID, 2014-2018 \$640,000

PI, Protecting Ecosystems and Restoring Forests in Malawi, USAID, 2014-2018 \$629,000

PI, *Monitoring and Mapping the Area, Extent and Shifting Geographies of Industrial Forests in the Tropics*, NASA, 2014-2017, \$541,938

PI, *India Forest PLUS*, USAID, 2012-2017, \$1,675,000

PI, *Strengthening Indonesian Capacity for Developing National Forest Carbon Inventory, Mapping and MRV Technical Systems*, California Governor's Climate and Forest Fund, 2013-2014, \$138,000

PI, *Carbon, Climate and Livelihoods*, UNEP, 2009-2012, \$968,808

PI, *Developing Small-Holder Agro-forestry Carbon Offset Protocols for Carbon Financial Markets*, Asia Pacific Network Japan, 2009-2010, \$40,000

Co-I, *Financial Analysis Tools for Small Holder Agro-forestry Carbon Sequestration Projects*, World Agro Forestry Center, Nairobi, Kenya, 2009-2011, \$59,932

PI, *Enhancing Global Scale Observations And Information on Tropical Forest Change Using Landsat Global Data Remote Sensing*, NASA, 2008-2010, \$682,168.

PI, *Pilot Project for Reduced Emissions from Deforestation in the Peruvian Amazon*, WWF, 2009-2010, \$64,303

PI, *What is The Global Rate And Extent of Tropical Deforestation; Forest Regeneration; Selective Logging; And Fragmentation?* NASA, 2004-2007, \$592,000

Co-I (with D. Clay), *Famine Early Warning System Network*, USAID/Chemonics, 2005 – 2010 , \$1,520,127

PI, *Global Tropical Rain Forest Information Center 2*, NASA, 2004 – 2008, \$4,167,000

PI, *Tropical Rain Forest Information Center*, NASA, 1997 – 2003, \$4,832,000

PI, *Water: Challenges at the Intersection of Human and Natural Systems*, NSF, 2004-2005, \$72,000

Co-I (with J. Bartholic), *Development of the Great Lakes Natural Resource Gateway*, National Park Service, 2003-2005, \$178,000

PI, *Spatial Data and Information for Land Use and Forest Assessment and Management*, Asia Pacific Network for Global Change Research, 2001- 2005, \$192,000

PI, *Remote Sensing Component of the Michigan Department of Environmental Quality's Lake Water Quality Assessment Monitoring Program*, USGS, 2001 – 2002, \$40,000

PI, *Regional, multi-scaled, multi-temporal land use and land cover data to support global change research*. Asia Pacific Network for Global Change Research, 2003 - 2005, \$131,960

Co-I (with R. Walker), *Pattern to Process: Research and Applications for Understanding Multiple Interactions and Feedbacks on Land Cover Change*, NASA, 2000 – 2004, \$641,675

PI, *Web Based Aerial Image Viewing System*, MI Department of Natural Resources, 2000-2001, \$24,857

Co-I (with S. Batzli), *Land Use Study Component - US31 Location Project*, Michigan DOT, 2000-2001, \$282,791

Co-I (with S. Gage), *Designing an Assessment Tool to Characterize the Impact of Changes in Land Use to Key Michigan Natural Resource Based Industries*, Public Sector Consultants, 2000- 2001, \$136,500

Co-I (with J. Qi), *GOFCA Data and Information for Tropical Forest Assessment and Management*, NASA, 2000 – 2003, \$374,000

PI, *SIVAM*, Raytheon Company, 1999 – 2008, \$839,370

Co-I (with D. Brown), *Upper Great Lakes Regional Earth Science Applications Center*, NASA, 1999 – 2003, \$400,000

PI, *Human Dimensions of Deforestation And Regrowth In The Brazilian Amazonia*, NASA, 1998– 2000, \$195,000

PI, *Measurement and Modeling of the Inter-Annual Dynamics of Deforestation and Regrowth in the Brazilian Amazon*, NASA, 1998 – 2003, \$1,224,163

PI, *Acquisition and Analysis of Large Quantities of Landsat 7 Data for Measuring Tropical Land Change*, NASA, 1997– 2000, \$631,000

PI, *Landsat Pathfinder - Humid Tropical Forest Project*, NASA, 1997 – 1999, \$318,000

PI, *Michigan State University Center of Excellence in Applications of Remote Sensing to Regional and Global Integrated Environmental Change*, NASA, 1997 – 2000, \$392,000

PI, *Use of SAR for Monitoring Deforestation and Secondary Growth in the Tropics*, NASA, 1998, \$47,000

PI, *Case Studies and Diagnostic Models of the Inter-Annual Dynamics of Deforestation in Southeast Asia: is the Missing Sink for Carbon in Land Use Change?*, NASA, 1997 – 2001, \$460,000